

The critical review of life cycle assessment studies according to ISO 14040 and 14044

Origin, purpose and practical performance

Walter Klöpffer

Received: 26 April 2011 / Accepted: 29 March 2012 / Published online: 24 April 2012
© Springer-Verlag 2012

Abstract

Purposes The revision of the ISO LCA (life cycle assessment) standards in October 2006 brought some changes of the critical review process compared to the older series ISO 14040–43 (1997, 1998, 2000a, b). Furthermore, the importance of LCA has grown rapidly in recent years, but this growth was not accompanied by a corresponding increase of knowledge about the voluntary and obligatory review processes. It is the intention of this paper to analyse the relevant standards and to present some personal experiences in conducting critical reviews.

Results and discussion A peer review for LCA studies was first proposed in the Society of Environmental Toxicology and Chemistry (SETAC) guidelines “A Code of Practice” (1993). The ISO standard 14040 (1997) took up this proposition and described three types of “Critical review” which are optional in general, but mandatory “for LCA studies used to make a comparative assertion that is disclosed to the public”. This strong prescription was reinforced in the revised standards ISO 14040 and 14044 (2006a, b) and even stricter, unambiguous formulations were added to the text. In addition, the minimum number of experts in a “review by interested parties” is now three (including the chair). Large panels with more than four experts are rare, but do occur occasionally.

Recommendations Out of personal experience, I strongly support the interactive (accompanying) mode of conducting the critical review process (ISO also allows the “a posteriori” mode). I also suggest the removal of some inconsistencies during the next update of the standards. No major changes are recommended, however, since ISO 14040+14044 has become

the reference standard for several other international standards based on the life cycle concept.

Keywords Critical review · Comparative assertion · ISO 14040 · ISO 14044 · LCA study · Peer review · SETAC

1 Introduction

The critical review plays an important role in the praxis of life cycle assessment (LCA) studies, but only a minor one in the scientific literature (Fava and Pomper 1997; Klöpffer 1997, 2000, 2005). Since my last detailed communication about this topic, a revision of the international LCA standards ISO 14040 (old), 14041, 14042 and 14043 (ISO 1997, 1998, 2000a, b) took place in such a way that two new standards, ISO 14040 (new) and 14044 (ISO 2006a, b; Finkbeiner et al. 2006), superseded the older series and are now the only valid ones. This necessitates a reconsideration of the role of the critical review. To reveal the main result right now: the critical review has become even more important and rigorous than before. In order to better understand the review process, the way LCA took in the decisive phase of beginning harmonisation is described first; it ended within a decade in the first set of ISO standards.

ISO 14040 and 14044, tightly bound together with one “shall”, is now considered the leading and most important international standard for environmental assessment according to the life cycle or cradle-to-grave or holistic method. It is a reference standard for other, more specialised norms (e.g., on environmental product declaration (ISO 14025), carbon footprint (ISO 14067, draft), eco-efficiency (ISO 14045, draft) and others. It is to expected, therefore, that the strict but flexible and unbureaucratic review process

W. Klöpffer (✉)
LCA Consult & Review,
Am Dachsberg 56E,
60435 Frankfurt am Main, Germany
e-mail: walter.kloepffer@t-online.de

designed for ISO 14040 will also influence the other standards (EC 2010a).

2 A short history of harmonisation and early standardisation: from peer review to critical review

The development of harmonisation started in the late 1980's when the relatively simple "proto-LCAs" (Klöpffer 2006) took an unexpected and still not fully understood upward swing. Since it was quite easy at that time to make (often premature) comparative statements about the environmental behaviour of product systems, there existed a considerable potential for the misuse of the young method. This was at least one reason among several to start a harmonisation and, later, standardisation of the different versions of "eco-balances" and "life cycle analyses" in order to create one generally accepted method, now called "Life Cycle Assessment (LCA)" (Fava et al. 1991, 1993). The most important event in the series of Society of Environmental Toxicology and Chemistry (SETAC) LCA activities was the workshop in Sesimbra (Portugal) immediately after the first SETAC World Congress in Lisbon, March 1993. The result of this workshop, the "Guidelines for Life-Cycle Assessment: A 'Code of Practice'" (SETAC 1993) not only produced a kind of standard, but also requested for the first time a peer review (the term "critical review" was introduced later by ISO) for each LCA. We read in Chapter 7 (Peer Review):

Among the benefits of peer review are:

1. The peer review process enhances the scientific and technical quality of LCAs.
2. The process helps to focus study goals, data collection, and provides a critical screening of study conclusions, thereby enhancing study credibility.

Furthermore, an "interactive peer review at various stages of the LCA" was proposed for the first time, especially for "LCA studies directed toward public audiences". Ideally, "this interactive peer review should be carried out in three phases:

- At the beginning of the LCA to review the goals, scope, boundaries, and the data collection planned
- After initial data collection or modelling, to review the progress and offer advice or comments
- At a final report stage, to review the adequacy of the study and the credibility of the conclusions.

These propositions are still useful and valid today.

Soon after the publication of the SETAC Guidelines (SETAC 1993), the preparation of the ISO standards started in Paris (Marsmann 1997, 2000). The first series of LCA standards used the SETAC guidelines as a blueprint. The only major change consisted in the changing of the last component

"Improvement assessment" (Fava et al. 1991; SETAC 1993) into "Interpretation" (Lecouls 1999; ISO 2000b). In addition, SETAC's sub-component "valuation" within "Impact Assessment" was boiled down by ISO to an optional step "weighting", strictly forbidden in the case of "comparative assertions" (see below). The same contempt is shown for any non science-based element in LCA, e.g., "subjective" allocation rules in the component Life Cycle Inventory (LCI).

The review process, now called "critical review", is described in the framework standard ISO 14040 (ISO 1997; Marsmann 1997). This was discussed in detail in a previous paper (Klöpffer 2005); here, only the essential statements regarding the critical process are repeated. First of all, three kinds of review were identified: the review by an independent internal expert, by an independent external expert and by "Interested parties" (§ 7.3.3, ISO 1997). This last mentioned, most demanding review is also called the panel method. It "shall" be used if "comparative assertions" derived from an LCA study are "disclosed to the public". Clearly, the potential for misuse (especially in marketing and advertisement) is highest if the results are published in one way or the other.

The procedure of the panel method is as follows (ISO 1997):

- The commissioner of the study "selects" (i.e., invites) an expert as chair of the panel
- The chair invites further experts (within the constraints of the budget)
- The inclusion of "other interested parties" (e.g., competitors, administrators, consumer advisors, environmental agencies or NGOs) is only optional, however

The first sentence implies that a person is invited to chair the panel, not an organisation. He or she has the main responsibility for the performance of the critical review and the review report. A consensus report is preferable but not required by the standard, diverging opinions can therefore put forward by the panel members and documented. The commissioner and/or the practitioner have the right to comment the critical review report, the comments are ("shall be") part of the LCA study report as well as the review report, e.g., as an annex to the main report.

The fact that the "interested parties" are only optional constitutes, of course, a contradiction in a "review by interested parties". This is discussed in section 3 in more detail, since the contradiction has not been removed during the update of the standards.

The original ISO 14040 (1997) also answered the question whether or not a critical review has to be performed:

In general, critical reviews of an LCA are optional and may utilize any of the review options outlined in [section] 7.3. A critical review *shall* be conducted for

LCA studies used to make a *comparative assertion* that is disclosed to the public and *shall* employ the critical review process outlined in 7.3.3.

The second sentence is very strong, strictly demanding a critical review in its toughest form, in a wording which became famous in the LCA community. “Shall” means in the ISO language about “must without exception”. This message is repeated in section 7.1 in a chapter which is entirely devoted to Critical review:

...In order to decrease the likelihood of misunderstandings or negative effects on external interested parties, critical reviews shall be conducted on LCA studies where the results are used to support comparative assertions.

The emphasis of this paragraph is on avoiding “misunderstandings”, etc., clearly an understatement. Much to the relief of all those conducting critical reviews according to section 7.3.3, we further read that “the fact that a critical review has been conducted should in no way imply an endorsement of any comparative assertion that is based on an LCA study”. Again, these wordings show the firm determination of the authors of ISO 14040 to avoid any misuse of LCA, e.g., in marketing or in politics, by the use of LCA-based claims which are not really well founded. The new standards are in this respect even more adamant (section 3).

3 The revised standards ISO 14040 and 14044 (2006a, b)

The four original standards 14040–43 (section 2) were replaced by two revised ones in October 2006: a framework norm again called 14040 (ISO 2006a) and a norm 14044 defining the requirements (“all shall”) (ISO 2006b). It was intended that there will be no changes in the contents of the “old standards”, but rather improve their presentation (Finkbeiner et al. 2006). ISO 14040 (new) and 14044 are connected with one “shall”, saying that if an LCA study is conducted according to the principles laid down in ISO 14040, the detailed rules and requirements of 14044 must be observed! Thus, it is not allowed to do an LCA just “in the spirit of 14040” (without sticking strictly to the requirements laid down in 14044) and claiming afterwards that the study was performed according to ISO! One may call this a trick, but it is an ingenious one.

The critical review is defined in 14040 section 3.4.4 (terms and definitions) as a “process intended to ensure consistency between an LCA and the principles and requirements of the International Standards on life cycle assessment

NOTE 1 The principles are described in ISO 14040

NOTE 2 The requirements are described in ISO 14044”

Most changes in the new standards, compared to the first series, concern the critical review process in an effort to make the definitions more precise (Finkbeiner et al. 2006). This is especially true for “comparative assertions”, as can be seen in the following revised sentence in ISO 14044:

In order to decrease the likelihood of misunderstandings or negative effects on external interested parties, a panel of interested parties shall conduct critical reviews on LCA studies where the results are *intended* to be used to support a comparative assertion *intended* to be disclosed to the public.

Taken literally, as a standard should be, this means that the mere aim or purpose to use LCA results for comparative assertions, again only intended, to be disclosed to the public, requires (again “shall”) a critical review according to the panel method. However, there is also in the new standard the contradiction between the heading of the section 7.3.3 (14040 old and new) and the content, saying that the inclusion of interested parties is only optional (“may”):

7.3.3 Critical review by panel of interested parties:

An external independent expert is selected by the original study commissioner to act as chairperson of a review panel of at least three members. Based on goal, scope and budget available for the review, the chairperson selects other independent qualified reviewers.

This panel *may* also include other interested parties affected by the conclusions drawn from the LCA such as government agencies, non-governmental groups, competitors and affected industries.

The ambiguity between title and content in ISO 14040 (1997) has not been removed in the new standard. The same statement is repeated in section 6.3 of the requirements standard ISO 14044 (2006b).

In the milder form of the critical review by an “independent expert”, the distinction between internal and external independent expert has been cancelled. An “internal independent expert” sounds like an oxymoron and certainly is such a contradiction in itself in the case of a small firm; in a big company, however, the quality, sustainability or product stewardship department may have LCA staff and the due independent status. At this point it should be mentioned that this type of critical review is not necessarily restricted to small LCA studies and one independent expert; small expert teams, e.g., an LCA method specialist and a data and technology specialist may perform the review together. This procedure does not require a formal chair. Such a review is the first choice for LCAs aiming at improvements, e.g., the comparison of an existing product system with a better one developed in the same company. This constitutes in general not a “comparative assertion”. Since the whole product system is analysed from cradle-to-grave, it seems unlikely

that a competitor fabricates (or performs in case of a service) exactly the same product, even if the function is the same. The critical review by an independent expert seems also appropriate for LCI studies, data collection and modelling (Klöpffer 2009). Requirements for this type of review have recently been formulated by the European Commission in a chapter of the ILCD Handbook (EC 2010b).

According to the standard ISO 14044, section 6.1, the following items have to (“shall”) be considered during any critical review:

The critical review process shall ensure that:

- the methods used to carry out the LCA are consistent with this International Standard;
- the methods used to carry out the LCA are scientifically and technically valid;
- the data used are appropriate and reasonable in relation to the goal of the study;
- the interpretations reflect the limitations identified and the goal of the study; and
- the study report is transparent and consistent.

This useful and well-composed list gives guidance for the reviewer(s) and actually serves as structure for the main part of most review reports. There are no absolute quality criteria (except the consistency with the international standard), but the most important component “Goal & Scope” is cited as point of reference. Therefore, this part of the LCA study should be scrutinized carefully already as a draft, as already proposed in the Code of Practice (SETAC 1993). It should be noted that this can only be done in an interactive review! The following parts (Life Cycle Inventory, Life Cycle Impact Assessment and Interpretation) should also be available as drafts for review, so that changes can be requested by the reviewers (if necessary), performed by the practitioner (if possible), and additional data can be provided by the commissioner or from suppliers and other sources. Finally, the reviewers have to check carefully (mostly having the draft final LCA report at hand) whether the LCI and LCIA have been performed according to the Goal & Scope chapter and properly discussed in the final component Interpretation. There has to be one smooth and logical line of arguments between the components, the first and the last one being equally important as the two technical/scientific middle components. This typical SETAC/ISO structure should also be clearly recognisable in the LCA report.

4 Practical aspects of the critical review process

The international LCA standards are precise in some points, but left room for interpretation in others (the SETAC Code of Practice is more practical in some aspects, especially for

the review process). With regard to the critical review process, not much is said about the way in which the panel cooperates with the two main actors, the commissioner and the practitioner. In the following, I mainly refer to the panel method, but similar considerations may be valid for the review by an independent external expert, except for the invitation of additional experts. The invitation of the co-referees (and “interested parties”) by the chair is a delicate duty, since these have to be experts (often with specific knowledge in technological details of the product systems), but also have to have the confidence not only by the chair, but also by commissioner and practitioner. Confidentiality agreements are signed by the reviewers in most cases, using standard forms provided by the commissioner. Contracts may be individually negotiated between commissioner and reviewers or the chair may submit a harmonized offer including working days and honoraria by the panel members. At this point it should be mentioned that the majority of reviewers do their duty as private consultants, even if employed in a company or authority. An allowance by the employer is needed in this case, but never checked during a review process (only the tax situation has to be cleared: with or without VAT?). Private or employed, the reviewers are responsible personally. There is no bureaucracy, no accreditation or other formal requirements. It should be noted, however, that the European “International Reference Life Cycle Data System (ILCD)” devotes two chapters of its recent handbook (EC 2010a, b) to reviewing, including other, more formal procedures applicable beyond the comparative product LCA discussed here. Also the UNEP/SETAC Life Cycle Initiative is preparing rules for global use in critical review processes.

The invitation of fellow reviewers by the chair should be agreed upon with the commissioner. The panel, commissioner and practitioner have to cooperate, despite the needed critical distance, especially in an interactive review. All data have to be provided for scrutiny, also and especially the data not included in the LCA study report for confidentiality reasons. The question about data has been one of the reasons why the critical review was created at all. Companies are in general very reluctant to lay them open (Frischknecht 2004) since they fear competitive disadvantages. Sometimes, the commissioner proposes panel members to the chair or the practitioner is commissioned with the duty to compose a panel. This can happen if the commissioner is not familiar with the LCA or only with the LCI part. The nominated chair should hold in reserve a veto if he or she is not convinced that one or the other co-referee proposed is not suited for the job.

The fact that the inclusion of “other interested parties” is only optional constitutes a contradiction, at least at first sight. There may be good reasons, however, for appointing only experts. A study with a small budget cannot afford a

large panel. It is also difficult to include competitors (one obvious group of “interested parties”). Proved solutions for both problems are:

- An industry association acts as study commissioner (in such associations competitors are members and often cooperate in environmental issues)
- Creation of a project advisory group by the commissioner which is invited to attend the project sessions; in such a group other companies in the supply chain, environmentalists, consumer advisors and representatives of environmental agencies can discuss the LCA and bring in their experience

Another aspect not mentioned in the standards only marginally concerns the communication. It depends on this aspect whether solutions are rapidly found if problems surface. The “critical review triangle” (©Klöpffer 2005), Fig. 1, symbolises the optimal, i.e., equally entitled, positioning of the three actors during a critical review:

- Commissioner
- Practitioner team
- Critical review panel

These groups are typically represented by the project coordinator (commissioner), the LCA project leader (practitioner) and the chair of the review panel. The communication between these persons should be well established; face-to-face meetings of the three groups, optionally including the advisory group (if there is any), help to improve the communication and are therefore preferable to phone conferences. This is not to say that only these persons should communicate, quite the contrary. The data and systems specialist will often have an intense communication with the persons doing the data acquisition and the calculations at the practitioner’s LCA group.

Out of experience I can assert that deviations from the triangle situation may lead to problems. Sometimes, the commissioner transfers his rights to the practitioner and does not interfere in the review business. This is far from welcome, since the triangle “collapses” in a kind of confrontation if difficulties emerge. Opinions by the commissioner are learnt only indirectly via the practitioner, if at all. An example is presented in (Klöpffer 2005). It may also happen that the LCA study was produced by an LCA

specialist in the company, so that to a certain degree Commissioner=Practitioner. Another variant is that only one member of the critical review panel (not necessarily the chair) has access to the confidential data (Klöpffer et al. 1995, 1996; Klöpffer 2005). Such arrangements should be specified in the contract between commissioner and critical review panel and, if relevant, be calculated.

Coming back to quality, credibility and potential misuse of LCAs, it can be said that a well working critical review triangle contributes to improve any LCA study. In an accompanying review with good communication, the commissioner has hardly a chance to push the study in a direction which might please his marketing people but not the environment (hired gun effect). The review team effectively backs the practitioner and thus contributes to the credibility of the LCA study. On the other hand, it also strongly supports the commissioner in his wish for unbiased high quality work, based on good data and models. Not only the practitioners, also the reviewers can lose their credibility and therefore both are highly interested in a correct performance of the LCA including the critical review process. Finally, the commissioner gets more for his money even if the results may differ from anticipated ones. My “Ceterum censeo” is (in contrast to old Cato who wished to destroy Carthage) that learning about the environmental consequences of product systems is the best use of LCA and that the critical review can contribute to this process.

A question of practical importance, since (nearly) proportional to the costs of a critical review, is the panel size. Before 2006, the average size was about three. My personal average was 2.7. Panel sizes ≥ 4 were exceptions. In the revised norm, the minimum size (including the chair) is three. My personal average since 2006–2007 increased to 3.3, but mainly due to an exceptionally large panel of seven which deserves to be emphasized (Lecouls and Klöpffer 2010). Henri Lecouls, the former convenor of ISO 14043 (Interpretation) (Lecouls 1999), acted as chair of the critical review panel consisting (in addition to the chair) of two international co-reviewers (L.-G. Lindfors and myself) and four representatives of interested parties (three from industry, one representative of an environmental NGO). The LCA study was performed by Ecobilan (Paris) for Aliapur (Lyon), the French monopolist for used tyres collection and recycling (Clauzade et al. 2010).

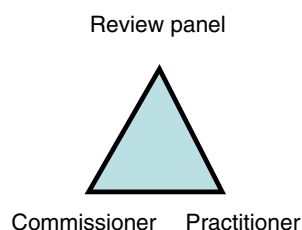


Fig. 1 “Review triangle”

5 Questions left open in the standards

5.1 Interactive (accompanying) or a posteriori review?

As already stated, ISO 14044 does not prescribe the interactive mode of the critical review, SETAC strongly recommended it with good reasons (SETAC 1993). In general, the

interactive mode is indeed preferable. Although somewhat more (reviewer-) time consuming at the beginning, it reduces the risk that new aspects surface at the end of the study which may delay its completing. An interactive review starts mostly with the draft Goal and Scope chapter and, preferably, a kick-off meeting to discuss the comments made by the review panel (the same is true for a review by an independent expert). The next document may already contain some LCIA results in addition to the LCI, but certainly not the interpretation. This is the best time for a data and systems check. Finally, the draft LCA study report including the results of the impact assessment and the interpretation is checked. In complex studies it is advisable to discuss the interpretation with the review panel before proceeding to sensitivity analyses, etc. The critical review report is written on the basis of the final draft of the LCA report. This can be done within a few weeks if the essential comments and points of criticism made by the reviewers were taken into account by the practitioner and accepted by the commissioner in the case of an active sponsor — in contrast to a sleeping one (see above the discussion of the “critical review triangle”). A second (or third) meeting may be helpful in the final phase, especially if there are diverging opinions within the triangle. If these cannot be solved, practitioner and/or commissioner have the right to post their comments about the critical review in the final study report (after the critical review). Both reports “shall” be part of the LCA study report.

If the critical review is conducted in the “a posteriori” mode there is a considerable risk of delay in the final phase of the project. The review team (or the independent expert) is confronted with the draft final report of the LCA study and has to judge it within a few weeks. If a serious flaw in the methodology or data quality should be detected by the reviewer(s), there is hardly a chance to do the necessary corrections at short notice. The project budget is in this stage in most cases exhausted (if not overdrawn) and the commissioner is in general reluctant to increase the funding. One exception to this may be the expectation of a very critical review statement, making the study worthless. This means, there is a chance to improve the study, but at the expense of additional money and time. The study may be delayed for several months.

5.2 What exactly is a comparative assertion?

Many comparative LCA studies appear in the scientific literature (Klöpffer 2007), but a critical review is often not mentioned.

Is this in contradiction to the standards analysed above? In principle yes, if it is claimed that the study has been performed according to the international standards. The International Journal of Life Cycle Assessment, for instance,

will accept such manuscripts if they are reviewed by at least two referees and according to the generally accepted rules of peer reviewing in scientific journals. This publication can, of course, be cited as a scientific paper, even as an LCA — but not as an LCA generated according to ISO (Klöpffer 2005). On the other hand, an LCA study prepared according to the standards has to contain a statement about this adherence and the critical review panel has to check whether this statement is included in the final report. Many LCA scientists, practitioners and commissioners, however, are not happy with this status quo since there may be “grey zones”, e.g., PhD students studying new impact assessment methods, using real data of real product systems, and best LCA practice. Are the results comparative assertions, although unintentional ones? There is a widespread feeling that the comparative assertion should be better defined. In section 3, “Terms and definitions” in both ISO 14040 and 14044, we read (emphasis is by the author) under 3.6:

comparative assertion

Environmental claim regarding the superiority or equivalence of one product versus a *competing* product that performs the same function

I think that this definition has to be taken literally: two (or more) products competing are necessary for a comparative assertion. In order to compete, there has to be a market. This means that if a product is produced in China for the Chinese market only (if there is such a product) it is not competing with a very similar product in, say Europe or USA and vice versa. In practice one should be careful anyway, however. Be careful with brand- and company names! One should ask the question: “Can I (as the publishing practitioner or scientist) be sued for making this LCA-based comparison (without critical review)?” Being informed about the products and markets is a precautionary measure. This knowledge can be gained from cooperation with industry associations during the data search, discussions with experts, reading technical literature and product information, etc.

6 Recommendations

Since this paper is a partial analysis of the international LCA standards and the “blueprint guideline” by SETAC, recommendations are addressed mainly to those responsible for the next update. With regard to the critical review, a few unclear formulations should be improved:

- Remove the contradiction concerning the “interested parties” and rename the review according to 14040, 7.3.3 and 14044, 6.2 into “review according to the panel method”.

- Better define the “comparative assertion” and give examples for cases where comparative assertion is actually the best term and cases where it is wrong; draw a line between (academic) research and competitive industrial management (including product promotion, etc.).
- Create a better awareness of the standards outside industry, consultancy and regulatory organisations (e.g., in the academic milieu)

No major changes are recommended, however, since ISO 14040+14044 has become the reference standard for several other international standards based on the life cycle concept.

For other institutions, academic, NGO, consulting, environment agencies:

- Provide training for future LCA practitioners, including
- Critical review
- Define profiles for critical reviewers and
- Minimum requirements for chairpersons, but
- Without creating any unnecessary bureaucratic burdens

Finally, I recommend to all commissioners of comparative LCAs to install interactive rather than “a posteriori” critical review. The results should not be used for any unfair marketing activities.

References

- Clauzade C, Osset P, Hugrel C, Chappert A, Durande M, Palluau M (2010) Life cycle assessment of nine recovery methods for end-of-life tyres. *Int J Life Cycle Assess* 15:883–892
- European Commission (EC) (2010a) ILCD Handbook: Review schemes for Life Cycle Assessment (LCA). Joint Research Centre—Institute for Environment and Sustainability. <http://www.jrc.europa.eu>
- European Commission (EC) (2010b) ILCD Handbook: Reviewer qualification for Life Cycle Inventory data sets. Joint Research Centre—Institute for Environment and Sustainability. <http://www.jrc.europa.eu>
- Fava JA, Denison R, Jones B, Curran MA, Vigon B, Selke S, Barnum J (eds) (1991) SETAC Workshop report: A technical framework for life cycle assessments. August 18–23 1990, Smugglers Notch, Vermont. SETAC, Washington, DC
- Fava J, Consoli FJ, Denison R, Dickson K, Mohin T, Vigon B (eds) (1993) Conceptual framework for life-cycle impact analysis. Workshop Report. SETAC and SETAC Foundation for Environ Education. Sandestin, Florida, February 1–7, 1992. SETAC, Pensacola (FL.)
- Fava J, Pomper S (1997) Life-cycle critical review! Does it work? Implementing a critical review process as a key element of the aluminium beverage container LCA. *Int J Life Cycle Assess* 2:144–153
- Finkbeiner M, Inaba A, Tan RBH, Christiansen K, Klüppel H-J (2006) The new international standards for Life Cycle Assessment: ISO 14040 and ISO 14044. *Int J Life Cycle Assess* 11:80–85
- Frischknecht R (2004) Transparency in LCA—a heretical request? (Editorial). *Int J Life Cycle Assess* 9:211–213
- International Standard Organization (ISO) (1997) Environmental management—Life cycle assessment: Principles and framework. ISO 14040, Geneva
- International Standard Organization (ISO) (1998) Environmental management—Life cycle assessment: Goal and scope definition and inventory analysis. ISO 14041, Geneva
- International Standard Organisation (ISO) (2000a) Environmental management—Life cycle assessment: Life cycle impact assessment. ISO 14042, Geneva
- International Standard Organisation (ISO) (2000b) Environmental management—Life cycle assessment: Interpretation. ISO 14043, Geneva
- International Standard Organisation (ISO) (2006a) Environmental management—Life cycle assessment: Principles and framework. ISO14040, Geneva
- International Standard Organisation (ISO) (2006b) Environmental management—Life cycle assessment: Requirements and Guidelines. ISO14044, Geneva
- Klöpffer W (1997) Peer (expert) review according to SETAC and ISO 1440. Theory and practice. *Int J Life Cycle Assess* 2:183–184
- Klöpffer W (2000) Praktische Erfahrungen mit Critical-Review-Prozessen. In: Stiftung Arbeit und Umwelt (eds) Ökobilanzen & Produktverantwortung. Dokumentation. ISBN 3-89384-041-9. Hannover, pp 37–42
- Klöpffer W (2005) The critical review process according to ISO 14040-43: an analysis of the standards and experiences gained in their application. *Int J Life Cycle Assess* 10:98–102
- Klöpffer W (2006) The role of SETAC in the development of LCA. *Int J Life Cycle Assess* 11(Special Issue 1):116–122
- Klöpffer W (2007) Publishing scientific articles with special reference to LCA and related topics. *Int J Life Cycle Assess* 12:71–76
- Klöpffer W (2009) Experiences with the critical review process of aluminium LCI data. *Int J Life Cycle Assess* 14(Special Issue 1):45–51
- Klöpffer W, Griebhammer R, Sundström G (1995) Overview of the scientific peer review of the European life cycle inventory for surfactant production. *Tenside Surfact Det* 32:378–383
- Klöpffer W, Sundström G, Griebhammer R (1996) The peer reviewing process—a case study: European life cycle inventory for surfactant production. *Int J Life Cycle Assess* 1:113–115
- Lecouls H (1999) ISO 14043: Environmental management • life cycle assessment • life cycle interpretation. *Int J Life Cycle Assess* 4:245
- Lecouls H, Klöpffer W (2010) Note on the critical review of the study “Life Cycle Assessment for the different used tyres recycling methods” prepared for Aliapur by Ecobilan. *Int J Life Cycle Assess* 15:893–895
- Marsmann M (1997) ISO 14040—The first project. With a foreword by Merkel A. *Int J Life Cycle Assess* 2:121–123
- Marsmann M (2000) The ISO 14040 family. *Int J Life Cycle Assess* 5:317–318
- Society of Environmental Toxicology and Chemistry (SETAC) (1993) Guidelines for Life-Cycle Assessment: A “Code of Practice”. From the SETAC Workshop held at Sesimbra, Portugal, 31 March–3 April 1993. Edition 1, Brussels and Pensacola, FL